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APPLICATION GUIDE FOR CURRENT TRANSFORMER

(*First Revision*)

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APPLICATION GUIDE FOR CURRENT TRANSFORMER

(First Revision)

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APPLICATION GUIDE FOR CURRENT TRANSFORMER

(First Revision)

0. FOREWORD

0.1 This Indian Standard (First Revision) was adopted by the Indian Standards Institution on 28 April 1983, after the draft finalized by the Instrument Transformers Sectional Committee had been approved by the Electrotechnical Division Council.

0.2 This standard was first published in 1967. This revision has been undertaken to upgrade the requirements that are necessary in view of the revision of the Indian Standards on current transformers.

0.3 This application guide is divided into four sections. Section 1 deals with general requirements regarding application of current transformers while Sections 2, 3 and 4 deal with special requirements regarding application of current transformers for use with measuring instruments and meters, with protective devices and for dual purpose (both for measurement and protection) respectively.

0.4 This standard is closely associated with and hence should be read along with IS : 2705 (Part 1)-1981*, IS : 2705 (Part 2)-1981*, IS : 2705 (Part 3)-1981* and IS : 2705 (Part 4)-1981*.

0.5 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS : 2-1960†. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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*Specification for current transformers :
Part 1 General requirements (*first revision*).
Part 2 Measuring current transformer (*first revision*).
Part 3 Protective current transformer (*first revision*).
Part 4 Protective current transformers for special purpose application (*first revision*).

†Rules for rounding off numerical values (*revised*).

1. SCOPE

1.1 This guide covers application of current transformers for use with both electrical measuring instruments and meters (measuring current transformers) and electrical protective devices in non-balanced protected equipment, for example, for the operation of overcurrent devices both of the non-directional and directional types and for the operation of earth fault devices with time-lag characteristics (protective current transformer).

1.1.1 Reference has been made to the use of current transformers for the dual purpose of measurement and protection and also for the operation of those protective devices which are more precisely dependent upon the magnitude and phase relationship of voltage and current, or upon the balance of the current.

1.2 This guide does not cover application of special purpose current transformer.

2. TERMINOLOGY

2.0 For the purpose of this guide, the following definition, in addition to those given in IS : 2705 (Part 1)-1981*, IS : 2705 (Part 2)-1981*, IS : 2705 (Part 3)-1981* and IS : 2705 (Part 4)-1981* shall apply.

2.1 Short-Time Factor (STF) — The ratio of the rated short time thermal current to the rated primary current.

SECTION 1 GENERAL

3. RATED CONTINUOUS THERMAL CURRENT

3.1 The maximum permissible temperature rise of a current transformer, carrying its rated continuous thermal current is given in Table 1 of IS : 2705 (Part 1)-1981*. Unless otherwise specified, the rated continuous thermal current is equal to the rated primary current. It should, therefore, be noted that normally current transformers have no continuous over-current rating. When selecting a current transformer, therefore, the rated primary current should be so chosen as to make it suitable for all but the momentary over-current that will occur in service. Where intermittent over-currents are frequent and severe, the manufacturer should be consulted as to a suitable current rating.

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*Specification for current transformers:

Part 1 General requirements (*first revision*).

Part 2 Measuring current transformers (*first revision*).

Part 3 Protective current transformers (*first revision*).

Part 4 Protective current transformers for special purpose application (*first revision*).

NOTE — Attention is drawn to the fact that the rated continuous thermal current of a current transformer may not be related to the rating of other associated equipment that is circuit breaker.

4. SHORT-TIME THERMAL CURRENT AND ITS DURATION

4.1 When determining the short-time current rating of a current transformer two factors have to be considered, one is the electromagnetic forces set up tending to damage the transformer mechanically, and the other the thermal effects tending to overheat the windings. The electromagnetic forces produced under short-time current conditions are largely independent of time, being determined by the highest peak value of the short-time current, the number of turns in the primary winding and the configuration of the coil. The forces experienced are less when the primary winding has the least number of turns.

4.2 Thermal effects depend on the rated short-time thermal current, its duration and the insulation media. The conditions for satisfactory operation are detailed in **7.7** of IS : 2705 (Part 1)-1981*. Bar-primaries of current transformers do not normally present any problems, heavy overcurrents for periods of three seconds being readily withstood.

4.3 The rated dynamic current being in turn dependent on the rated short-time thermal current, it is desirable that purchasers should inform the manufacturer regarding the magnitude and duration of the short-time thermal current to be withstood. The value of short-time thermal current should preferably be ascertained from the actual short-circuit level of the system at the point of installation of the current transformer. Alternatively, the short-time thermal current should be determined from the consideration of the rated symmetrical breaking capacity of the circuit breaker with which the current transformer will be employed.

4.4 It should be borne in mind that lower the class of accuracy and smaller the rated output and the accuracy limit factor, the stronger the transformer can be made mechanically and as will be seen from the Tables 1 and 2, the higher may be its short-time current. The higher the rated output, accuracy and short-time current called for, the larger will be transformer and the construction will be more difficult and costly.

Tables 1 and 2 show the short-time factors normally obtainable economically, corresponding to rated output, accuracy class and rated time of short-time current for wound-primary current transformers.

Bar primary transformer with a higher rated primary current should be selected if the short time factors are higher than the values indicated in Tables 1 and 2.

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*Specification for current transformers : Part 1 General requirements (*first revision*).

TABLE 1 MAXIMUM SHORT-TIME FACTORS OBTAINABLE ECONOMICALLY, CORRESPONDING TO RATED OUTPUT, ACCURACY CLASS, ACCURACY LIMIT FACTOR AND RATED TIME FOR WOUND-PRIMARY MEASURING CURRENT TRANSFORMERS

(*Clause* 4.4)

Accuracy	Rated Output VA	Short Time Factors Obtainable Corresponding to Rated Times Below		
		0·5 sec	1·0 sec	3·0 sec
(1)	(2)	(3)	(4)	(5)
0·1	5	325	225	125
	10	200	125	75
	15	150	100	60
	30	85	60	35
0·2	5	500	350	200
	10	325	250	135
	15	275	200	110
	30	150	100	60
0·5	5	750	525	300
	10	500	350	200
	15	375	275	150
	30	200	125	75
1	5	1000	700	400
	10	675	475	275
	15	500	350	200
	30	275	200	110
3	5	1000	700	400
	10	675	475	275
	15	500	350	200
	30	275	200	110
5	5	1000	700	400
	10	675	475	275
	15	500	350	200
	30	275	200	110

TABLE 2 MAXIMUM SHORT-TIME FACTORS OBTAINABLE ECONOMICALLY, CORRESPONDING TO RATED OUTPUT, ACCURACY CLASS, ACCURACY LIMIT FACTOR AND RATED TIME FOR WOUND-PRIMARY PROTECTIVE CURRENT TRANSFORMERS

(*Clause* 4.4)

ACCURACY CLASS	RATED OUTPUT VA	SHORT TIME FACTORS OBTAINABLE CORRESPONDING TO RATED TIMES BELOW		
		0·5 Sec	1·0 Sec	3·0 Sec
(1)	(2)	(3)	(4)	(5)
5P 5	5	550	400	225
	10	375	275	150
	15	275	200	110
	30	125	75	50
5P 10	5	375	275	150
	10	225	150	90
	15	150	100	60
	30	—	—	—
5P 15	5	275	200	110
	10	150	100	60
	15	85	60	35
	30	—	—	—
5P 20	5	200	125	75
	10	100	75	40
	15	—	—	—
	30	—	—	—
5P 30	5	125	75	50
	10	—	—	—
	15	—	—	—
	30	—	—	—
10P 5	5	750	525	300
	10	425	300	175
	15	375	275	150
	30	150	100	60
10P 10	5	425	300	175
	10	275	200	110
	15	200	125	75
	30	—	—	—
10P 20	5	275	200	110
	10	125	75	50
	15	85	60	35
	30	—	—	—
10P 30	5	150	100	60
	10	85	60	35
	15	—	—	—
	30	—	—	—

4.5 Maximum VA Output of Bar-primary and Bushing Current Transformers — The maximum output at which a current transformer will give a certain class of accuracy is dependent upon its ampere-turns at rated primary current and there is thus an upper limit to the rated output to be expected from a bar-primary or bushing current transformer dependent upon its rated primary current.

Table 3 gives the maximum output normally practicable for bar-primary or bushing current transformers of various accuracy classes and rated primary currents. The table is based on the assumption that the diameter of the bushing insulator over which the core and secondary windings are to be threaded does not exceed 90 mm. The figure may therefore be taken as applying to normal insulators for circuits up to 33 kV where the space available is adequate. If, however, the diameter of the bushing insulator exceeds 90 mm or the space available is inadequate it will be necessary for the burden to be reduced or for the permissible errors to be increased.

TABLE 3 RELATIONSHIP BETWEEN NORMAL PRACTICAL OUTPUT AND RATED PRIMARY CURENT OF BAR-PRIMARY AND BUSHING CURRENT TRANSFORMERS

		RATED PRIMARY CURRENT (AMPERES)							
TYPE	CLASS	60 VA	75 VA	100 VA	150 VA	200 VA	300 VA	400 VA	500 VA
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Measuring transformers	0·1					2·5	5	10	15
	0·2				2·5	5	15	30	30
	0·5			5	10	15	30	30	30
	1	2·5	5	10	15	30	30	30	30
	3	5	7·5	15	30	30	30	30	30
	5	5	7·5	15	30	30	30	30	30
Protective transformers	5P 10	—	—	10	15	15	30	30	30
	10P 10	7·5	7·5	10	15	15	30	30	30

NOTE — The output of protective transformers quoted are for an accuracy limit factor of 10, and the outputs for other accuracy limit factors will be inversely proportional to the factor.

4.6 All current transformers other than those used for testing purpose should be capable of withstanding for the prescribed time, the maximum through fault current to which they may be subjected in service.

5. INSULATION LEVEL

5.1 The insulation level should be coordinated with that of other apparatus on the system and should be one of the standard levels given in Tables 2 and 3 of IS : 2705 (Part 1)-1981*. In selecting the insulation level of a current transformer for a particular application the following factors should be considered (each winding should be considered separately):

a) Highest system voltage,

b) System earthing, and

c) Degree of exposure to over voltages.

5.2 Highest System Voltage — The highest system voltages normally associated with the nominal system voltages are stated in Tables 2 and 3 of IS : 2705 (Part 1)-1981*. The insulation level should be chosen from these tables corresponding to the selected highest system voltage. If system conditions result in a highest system voltage which is greater than that associated with the nominal system voltage given in Tables 2 and 3 of IS : 2705 (Part 1)-1981* then consideration should be given to the selection of an insulation level based on the next higher value of highest system voltage in these tables. The highest system voltage should not be confused with either.

a) nominal system voltage, and

b) rated voltage of the current transformers.

5.3 System Earthing — The usual conditions of the system neutral are described in **5.3.1** to **5.3.4**.

5.3.1 *System Neutral Effectively Earthed* — System neutral is earthed in such a manner that the co-efficient of earthing does not exceed 80 percent. This condition is met when for all switching, operating and supply conditions, the ratio of zero sequence reactance of the system to its positive sequence reactance is less than 3, and the ratio of the zero sequence resistance to the positive sequence reactance is less than 1. Reduced insulation level as given in Table 3 of IS : 2705 (Part 1)-1981* appropriate to the highest system voltage is normally applicable to this condition.

NOTE 1 — A system in which all power transformers have star connected windings with all neutrals solidly (directly) earthed is regarded as being effectively earthed.

NOTE 2 — A system in which some of the transformers have star connected windings without solidly earthed neutrals or have delta connected windings may be considered as being effectively earthed, if calculations by the method of symmetrical components show that the 80 percent coefficient of earthing criterion given above is met.

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*Specification for current transformers : Part 1 General requirements (*first revision*).

NOTE 3 — The inclusion of a single-turn bar primary current transformer between the transformer neutral and earth does not preclude the ssytem from being classified as effectively earthed. Similarly, the inclusion of multi turn primary current transformer between the transformer neutral and earth does not preclude the system from being classified as effectively earthed, provided that after allowing for the effective reactance of the primary of the current transformer, the 80 percent coefficient of earthing criterion is met.

5.3.2 *System Neutral Isolated* — In such a system no intentional connection is made to earth except through indicating, measuring or protective devices of very high impedance. The operating condition may involve the adoption of an insulation level higher than that would normally be selected for full insulation as given in Table 3 of IS : 2705 (Part 1)-1981* appropriate to the highest system voltage.

5.3.3 *System Neutral Resonant Earthed* — System neutral is earthed at one or more points through arc suppression coils, where it is usually the intention that line to earth faults shall be either:

a) self clearing without interruption of supply or cleared by automatic disconnections within a few seconds, or

b) cleared by mannual disconnection but allowed to persist until it is convenient to locate and isolate.

5.3.3.1 Full insulation level is normally applicable to this condition.

5.3.3.2 If under condition (b) above, it is contemplated that the system will be operated with one line earthed for a period exceeding 8 hours in any 24 hours, or an aggregate of 125 hours per annum, consideration should be given to the selection of a higher insulation than full insulation, appropriate to the highest system voltage.

5.3.4 *System Neutral Non-effectively Earthed* — System neutral is earthed through resistors or reactors other than those covered by **5.3.3** or earthed directly at a limited number of points such that the coefficient of earthing may exceed 80 percent. Full insulation level appropriate to the highest system voltage is applicable to this condition.

For the other cases where there is no intention for connection to earth except through indicating, measuring or protective devices of a very high impedance or where the duration of earth fault exceed the period referred to above, the manufacturer should be consulted.

5.4 Exposure to Over Voltages

5.4.1 *Electrically Non-exposed* — Here the apparatus is not subjected to over voltages of atmospheric origin. Such installations are usually those connected to networks consisting predominantly of underground cable. An

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*Specification for current transformers: Part 1 General requirements (*first revision*).

impulse level need not be specified under this condition. However, consideration should be made regarding Note 1 and Note 2 given in **5.4.2**.

Apparatus may be required for installations which are semi-exposed to over voltages of atmospheric origin, that is, to over voltages of a magnitude less than for an exposed installation. Such installations are usually connected to overhead transmission lines through double winding transformers, or cable, which may reduce the amplitude of incoming over voltages. These cases require special consideration.

5.4.2 *Electrically Exposed* — Here the apparatus is subjected to over voltage of atmospheric origin such installations are usually those connected to overhead transmission lines, either directly or through a short length of cable.

Current transformers for electrically exposed installations should be designed to withstand impulse voltage test, the value should be in accordance with Table 3 of IS : 2705 (Part 1)-1981* where the earthing conditions permit, the use of a surge diverter of suitable characteristics may justify the choice of an insulation level lower than that corresponding to the highest system voltage.

NOTE 1 — In addition to over voltages of atmospheric origin, there may be over voltages generated elsewhere in the system to which current transformers installed in electrically exposed and electrically non-exposed situations may be subjected to over voltages generated elsewhere in the system, for example, over voltages resulting from the operation of a circuit breaker when switching on inductive or capacitive circuit or the forced interruption of the magnetising current of power transformer.

NOTE 2 — In all instances it is desirable to ensure that over voltages are limited to a value not exceeding 80 percent of the impulse test level of the windings by installation of suitable protective devices, such as surge diverters or protective rod gaps.

SECTION 2 APPLICATION OF MEASURING CURRENT TRANSFORMERS

6. RATED OUTPUT

6.1 Since the performance of a current transformer depends to some extent on the connected burden, it is desirable that the rated output should be as near to in value but not less than to the actual output at which the transformer is to operate. Ordering a current transformer with a rated output considerably in excess of required output may result in increased errors under operating conditions. This is due to the turns correction being

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*Specification for current transformers: Part 1 General requirements (*first revision*).

chosen for the rated burden and thus being excessive for a much lower burden.

6.2 The burden is composed of the individual burdens of the instruments or meters or both and the connecting leads. When the length of the connecting leads is such that the impedance of leads at 5 Amp secondary current would be excessive, consideration should be given to the use of a rated secondary current of a lower value in accordance with IS : 2705 (Part 1)-1981*.

7. ACCURACY CLASS

7.1 It is undesirable that a higher class of accuracy should be called for that is necessary for the duty required. To do so is uneconomical and may involve modifications to the switchgear without serving any useful purpose.

7.2 The accuracy classes recommended below are intended as a guide in the selection of measuring current transformers:

Application	*Class of Accuracy* [*see* **3.1** of IS : 2605 (Part 3)-1981*]
a) For precision testing, or as a sub-standard or testing laboratory current transformers	0·1
b) For laboratory and test work in conjunction with high accuracy indicating instruments, integrating meters and also sub-standard for testing industrial current transformers	0·2
c) For precision industrial metering	0·5
d) For commercial and industrial metering	0·5 or 1
e) For use with indicating and graphic wattmeters and ammeters	1 or 3
f) For purpose where the ratio is of less importance, for example, ammeters where approximate values are required	3 or 5

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*Specification for current transformers: Part 3 Protective current transformer (*first revision*).

7.3 Typical values of VA burden imposed by different meters are given below:

Instrument	*VA Burden*
a) Ammeters	3
b) Current coils of wattmeter and power factor meters	5
c) Current coils of Kwh, kVar meters	5
d) Recording ammeters	3
e) Current coils of recording power factor meters and wattmeters	5

SECTION 3 APPLICATION OF PROTECTIVE CURRENT TRANSFORMERS

8. GENERAL

8.1 This is only a general guide, useful in determination of the appropriate ratings of a protective current transformer for a specific purpose. In case of doubt or difficulty the manufacturer should be consulted.

8.2 The determination of the rating of a protective current transformer is dependent on its application and guidance is given in respect of rated burden, rated accuracy limit factor and accuracy class. Care is necessary in this determination owing to the diversity of the numbers and the characteristics of the devices intended to be used with protective current transformers and of the ways of expressing the burdens of these devices.

9. RATED BURDEN

9.1 The burden on a protective current transformer is composed of the individual burdens of associated relays or trip coils, instruments (when used) and the connecting leads.

9.2 When the individual burdens are expressed in Ohmic values, the total burden may be computed by addition. This total Ohmic burden should then be converted to a VA burden at the rated secondary current.

9.3 When the individual burdens are expressed in terms of VA, convert at a common base before they may be added together to form the total computed burden. This common base shall be the rated secondary current of the current transformer.

9.4 Although it is usual to add the individual burdens arithmetically, it is more correct to add them vectorially and it may be advantageous to do so, if this would lead to a small or more economical design.

9.5 Normally, the standard VA rating nearest to the burden computed should be used, but attention is drawn to the fact that a device may have an impedance with one or more of the following characteristics.

9.5.1 The impedance is constant, regardless of the current setting, subject to **9.5.4** (for example, untaped relay coils).

9.5.2 The impedance changes with the current setting (notably in trip coils, relays with tapped coils).

9.5.3 The impedance decreases when the current passing through the coil exceeds the current setting.

9.5.4 The impedance changes with the changed position of the armature of the relay or trip coil.

9.6 When the devices having the characteristics referred to in **9.5.1** and **9.5.2** are set to operate at current differing from the rated secondary current of the transformer, the VA burden (*Pe*) which is effectively imposed (effective burden) on the current transformer at rated secondary current is given by the following formula:

where

$$Pe = Pr\left(\frac{Is}{Ir}\right)^2$$

Pe = effective VA burden on the current transformer,

Pr = VA burden of the device at the current setting,

Is = Rated secondary current of the current transformer, and

Ir = Current setting of the device.

9.7 In selecting the most suitable standard rated output it is undesirable to specify a value which substantially exceeds the burden as computed above to do so might result in a.transformer unduly large dimensions.

9.8 When nearest standard VA rating is less than the total computed burden, it is usually satisfactory to adopt the standard, particularly when a part of the burden has the characteristics referred to in **9.5.3** above, since this results in a reduced impedance at the accuracy limit current. In instances of doubt, however, the manufacturer should be consulted.

10 RATED ACCURACY LIMIT FACTOR (CLASSES 5P AND 10P TRANSFORMERS)

10.1 In determining the appropriate accuracy limit factor for a given application, the important point to consider is the maximum value of primary current up to which maintenance of ratio is required; other factors, however, are also involved. The capabilities of a protective current transformer are determined by the primary ampere-turns, the core dimensions and material, and they are roughly proportional to the product of the rated burden and the rated accuracy limit factor. This is dealt with in **11**.

11. CORRELATION OF BURDEN AND ACCURACY LIMIT FACTOR (CLASS 5P AND 10P TRANSFORMER)

11.1 Accuracy limit factor higher than 10 and rated burdens higher than 15 VA are not recommended for general purposes. It is possible, however, to combine a higher rated accuracy limit factor with a lower burden rating and vice-versa; but when the product of these two exceeds 150, the resulting current transformer may be uneconomical or of unduly large dimensions or both. Moreover, it may be difficult to attain a product of 150 if the current transformers are of the wound-primary type with low ratio and high rated short-time thermal current.

11.2 It is important to note that for a given protective current transformer the accuracy limit factor and the burden are interrelated, that is, a decrease in its burden will automatically increase its accuracy limit factor and vice-versa. For example, the reduction in effective connected burden which results from changing the tap setting of an inverse-time overcurrent relay from 100 to 200 percent will enable the current transformer to supply a higher secondary current without its composite error exceeding the limit of its accuracy class.

12. ACCURACY CLASS

12.1 The accuracy class required of protective current transformer is dependent upon the particular application and some guidance on its selection with particular regard to associated value of rated accuracy limit factor and rated burden is given in **12.2**, **12.3** and **12.4**.

12.2 Instantaneous Over Current Relays and Trip Coils

12.2.1 In general a class 10P transformer should be sufficiently accurate. A secondary current greatly in excess of the value to cause operation serves no useful purpose, and a rated accuracy limit factor of 5 should be adequate.

12.2.2 When such relays are set to operate at high values of over current, say from 5 to 15 times the rated primary current, the accuracy limit factor shall be atleast as high as the value of the setting used, or the secondary current may never reach that value.

12.2.3 When a relay with a high setting forms part of an equipment with a high total VA burden it may often prove advantageous to operate the high set relay from a separate current transformer. This avoids the problem of having to provide a current transformer with a high burden combined with a high accuracy limit factor. For example, if a high set relay with a burden of 5 VA requires an accuracy limit factor of 15 and if the total burden is 20 VA, the product of these two quantities would be 300, which as indicated in **11**, would present certain difficulties. If, however, this high set relay is operated from a separate current transformers, that current transformer need only have a rated burden of 5 VA and on accuracy limit factor of 15, giving a product of 75, and the other current transformer operating the rest of equipment, a rated burden of 15 VA and an accuracy limit factor of say 10, giving a product of 150.

12.2.3.1 Moreover, the current transformer operating the high-set relay may be allocated an appropriately higher rated primary current, thereby reducing the required accuracy limit factor.

12.2.3.2 In these instances both current transformers may be class 10 P, one being designated 5 VA class 10P15 and the other 15 VA class 10P10.

12.3 Over Current Relays with Inverse and Definite Minimum Time Lag Characteristics — In general for both directional and non-directional relays a class 10P transformer should be used.

12.4 Earth Fault Protective Relays with Inverse and Definite Minimum Time Lag Characteristics — The requirement of current transformers used with earthfault protective schemes involving the use of 3-line current transformers (with or without a neutral current transformer) and using relays with inverse and definite minimum time lag characteristics (both non-directional and directional) are dependent upon the characteristics of the protective system itself. These characteristics and the corresponding current transformer may be classified in accordance with **12.4.1**, **12.4.2** and **12.4.3**.

12.4.1 Schemes in which phase fault stability and accurate time grading are not required—class 10 P current transformers in which the product of rated burden and rated accuracy limit factor approaches 150 should be used provided that the earth fault relay is not set below 20 percent of the rated secondary current of the associated current transformers and that burden of the relay at its current setting does not exceed 4 VA.

NOTE — Phasefault stability denotes the non-operation of the earthfault relay under phasefault conditions.

4.2 *Schemes in which Phasefault Stability of Accurate Time Grading or Both are required*

12.4.2.1 Class 5 P current transformers in which the product of rated burden and rated accuracy limit factor approaches 150 should be used. They are in general suitable for ensuring phasefault stability up to 10 times the rated primary current and for maintaining time grading of the earthfault, relay up to values of current of the order of 10 times the earthfault setting provided that:

a) phase burden effectively imposed on each current transformer does not exceed 50 percent of its rated burden,

b) rated accuracy limit factor is not less than 10,

c) earthfault relay is not set below 30 percent, and

d) burden of the relay at its current setting does not exceed 4 VA.

12.4.2.2 When system conditions demand the maintenance of time grading up to values of current in excess of 10 times the earthfault setting, consideration should be given to one or more of the following courses:

a) Use of a higher relay setting,

b) Use of an earthfault relay having a burden of less than 4 VA at its setting, and

c) Use of current transformers having a product of rated burden and rated accuracy limit factor in excess of 150.

12.4.2.3 In certain cases satisfactory time-grading and phasefault stability may be obtained with current transformers having errors exceeding those of class 5P. A protective scheme on this basis should be considered as a whole, and if necessary the advice of the manufacturer should be sought.

12.4.2.4 For ensuring the correct protection scheme in which phasefault stability or accurate time-grading are required, the selection of accuracy limit factor should be made carefully. For example, in a system where the earthfault currents are expected to be more than the phasefault currents, the accuracy limit factor selected should be such, so as to give correct working of the earthfault relays. In case it is not possible to select a current transformer with a higher accuracy limit factor, then the same results may be achieved by imposing a phase burden on each current transformers not exceeding 50 percent of its rated burden thereby increasing the accuracy limit factor indirectly to twice the value

Due consideration should be given to the type of relay and the burden for selecting proper current transformer.

12.4.3 Other forms of protection subject to the agreement of the manufacturer of the protective relays, class 5P and class 10P transformers may be suitable for certain forms of biased differential, directional and distance measuring protection.

For current transformers for certain applications of directional relays, the phase error may be particularly important up to the maximum through fault current which can flow through the primary windings and in this connection it should be noted that there is an upper limit of phase error corresponding to a value of composite error (*see* Table 1 and Appendix C) of IS : 2705 (Part 3)-1981*. Current transformers for distance measuring protection should maintain their class accuracy up to the maximum through fault current which can flow through their primary windings when the required relay burden is connected to their secondary windings. It should be noted that the magnitude and power factor of the burden of certain types of distance measuring equipments may change during operation of the various relay equipments may change during operation of the various relay elements under fault conditions and this fact should properly be taken into account in calculating the burden which will be imposed on the current transformers.

Where closer accuracy than that provided by class 5 P or class 10 P is required the requirements should be specified in terms of class PS.

13. CLASS PS TRANSFORMER PROTECTION

13.1 It should be noted that IS : 2705 (Part 3)-1981* applies to protective current transformers intended for use in non-balanced protective equipment, for example, for the operation of over current devices both of the non-directional and directional types and to protective current transformers used for the operation of earthfault devices with time-lag characteristics. When the operation of the protective equipment is more precisely dependent upon the magnitude and phase relationship of voltage and currents, for example, earthfault protection in resonant earthed networks, or upon the balance of current as, for example, instantaneous earthfault protection and differential protection, the current transformers may require characteristics which cannot conveniently be expressed in the terms used for accuracy classes 5 P and 10 P.

13.2 For such applications, the current transformer characteristics are normally specified in the following terms:

a) Knee-point voltage,

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*Specification for current transformers: Part 3 Protective current transformers (*first revision*).

b) Exciting current at the knee-point voltage or at a percentage thereof or both, and
c) Resistance of the secondary winding.

The values of the above terms are so dependent on the protective gear involved and the requirements are so numerous and varied that useful guidance cannot be given in this guide. In such cases the designer of the protective system should specify the additional requirements that may be necessary, for example:

a) For certain applications of directional relays the current transformer phase error may be particularly important up to the maximum through fault current which can flow through the primary windings,

b) For distance measuring protection, the current transformers should maintain their accuracy up to the maximum through fault current which can flow through their primary windings when the required relay burden is connected to their secondary windings. It should be noted that the magnitude and power factor of the burden of certain types of distance measuring equipment may change during operation of the various relay elements under fault conditions and this fact should properly be taken into account in calculating the burden which will be imposed on the current transformers, and

c) For protective schemes requiring close balance of the secondary currents from different phases or circuits, the current transformer turns ratio error may have to be limited. Such current transformers are required to be so designed, that balance is maintained with the protective system when maximum through fault current is flowing through the primary windings of the current transformer used for this system, that is, stability of the protection shall be assured, whether in the transient or in the steady state, up to the maximum through fault current which can be passed in service through their primary windings.

13.3 High speed protective schemes, such as restricted earthfault protection, differential protection, bus-zone protection, etc, which require close balance of the secondary current are subject to the effect of current transformer saturation from both ac and dc components of the fault current. If the power system has a large L/R ratio, the dc component of fault current decays slowly and transient saturation of the current transformer could occur since the current transformer core is magnetized with a unidirectional current. Residual flux may also be present in the core, the direction and magnitude depending upon the point on the primary current wave at which the previous switching operation occurred, and also upon, the remanance of the current transformer core material. If the residual flux and the flux due to the dc component of fault current are in the same direction, then together with the ac component of the fault current, the core may saturate and harmonic spill currents will flow through the relay, possibly causing incorrect tripping. To minimize the effect of current transformer core saturation under a symmetrical fault, it is common practice to use a stabilizing resistor in series with low impedance high speed relays.

14. FACTOR AFFECTING THE CHOICE OF PROTECTIVE CURRENT TRANSFORMERS

14.1 Certain important factors which should be taken into consideration while choosing the protective current transformers are outlined below. The importance of matching the current transformers to the relays cannot be over stressed and relay and current transformer manufacturers should be consulted on specific applications.

14.1.1 The operating time of inverse definite minimum time-lag (IDMTL) relays may be affected on account of saturation of current transformers. Current transformer saturation may cause harmonics which may increase the time of operation of IDMTL relays. While selecting the current transformers and where fault current is adequate, it should be ensured that current transformers do not saturate up to at least 20 times the relay setting. This may be achieved sometime by choosing a relay with a low VA burden or a current transformer with a higher ratio.

14.1.2 If current transformers with higher VA output and rated accuracy limit factor (and thus higher knee-point voltage) than what is required is selected, current transformers may be able to produce higher secondary current under fault conditions depending upon the actual primary fault current and the burden connected. This may result in causing excessive heating in the relay. This factor is specially important for current operated relays with time delay as the relay coil may burn out before fault is cleared.

14.1.3 Time-grading of inverse-time relays in systems employing high ratio current transformers on certain circuits and low ratio current transformers on other circuits may not always be as straight forward as would appear at first sight. While a high ratio current transformer may not saturate for high infeed fault, a low ratio current transformer would probably saturate and the secondary current supplied by this current transformer would contain a considerable proportion of harmonics, the most predominant being the third harmonics. Even if the high ratio current transformer saturates under fault conditions, the harmonic content in the high ratio current transformer would be less than in the low ratio current transformer. The performance of induction disc relay under conditions of saturation of current transformers is very considerably affected by the degree of saturation and the attendant harmonic contents at any given multiple of plug setting, higher harmonic contents resulting in higher operating times. The adverse effect is particularly serious when very poor quality current transformers are employed which saturate even at low multiples of plug setting of the over current relay. From the foregoing considerations it is evident that, if sufficient attention is not paid to the actual relay performance, then the desired time-discriminations and times of operation may not be obtained even if superficially satisfactory nominal settings are used on the relay.

14.1.4 For distance protection, if current transformers are not of adequate knee-point voltage it may result in producing higher operating time. A transient saturation actor (X/R) of primary system should be taken into consideration while calculating the knee-point voltage required from the current transformers to allow for transient saturation.

14.1.5 While selecting the current transformers for balanced protective system, for example, differential protection and restricted earthfault protection, it should be ensured that under external faults current transformers saturation and mismatch does not produce unbalance in the relay operating circuit. At the same time under internal faults, current transformer should produce adequate output to ensure that operating time of the relay is not exceeded.

14.1.6 Current transformers should not consume excessive magnetizing current. If magnetizing current is high, it may result in higher primary fault settings in case of current operated lays and may use under reaching in case of distance relays. However, a very low value of magnetizing current should not be specified as it may result in larger and costly current transformers.

SECTION 4 APPLICATION OF DUAL PURPOSE CURRENT TRANSFORMERS

15. DUAL PURPOSE APPLICATION

15.1 The requirements for a protective current transformer differ radically from those of a measuring current transformer. It is essential that a measuring transformer is accurate within the normal range of current up to 120 percent of rated current, or in the case of a transformer with an extended current rating up to one of the values stipulated in **4.2** of IS : 2705 (Part 2)-1981*. Accuracy is not required on high over current. It is, in fact, an advantage if the current transformer saturates at moderate over current, since this tends to relieve the measuring instruments of the severe train caused by heavy over current. A protective current transformer has to be accurate up to the rated accuracy limit primary current whereas on the other hand it is not usually required to be accurate below rated current.

It follows that the difficulties of producing a dual purpose current transformer are accentuated when high accuracy is required for measuring purposes or when a high accuracy limit factor is needed for protective purposes or both.

15.2 The question of using a single current transformer for the dual purpose of protection and measurement may be decided by considering all relevant factors, such as design, cost, space, and the capability of the instruments of withstanding high currents.

15.3 A current transformer for the dual purpose of production and measurement will have both a protection and a measurement rating.

15.4 When dual purpose current transformers are used it should be ensured that under maximum fault current no damage is caused to meters and instruments.

15.5 When such a transformer is used for both purposes simultaneously and the rated burdens for measurement and protection differ, the total connected burden shall not exceed the lower of the two rated burden.

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*Specification for current transformers : **Part 2 Measuring current transformers** (*first revision*).

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